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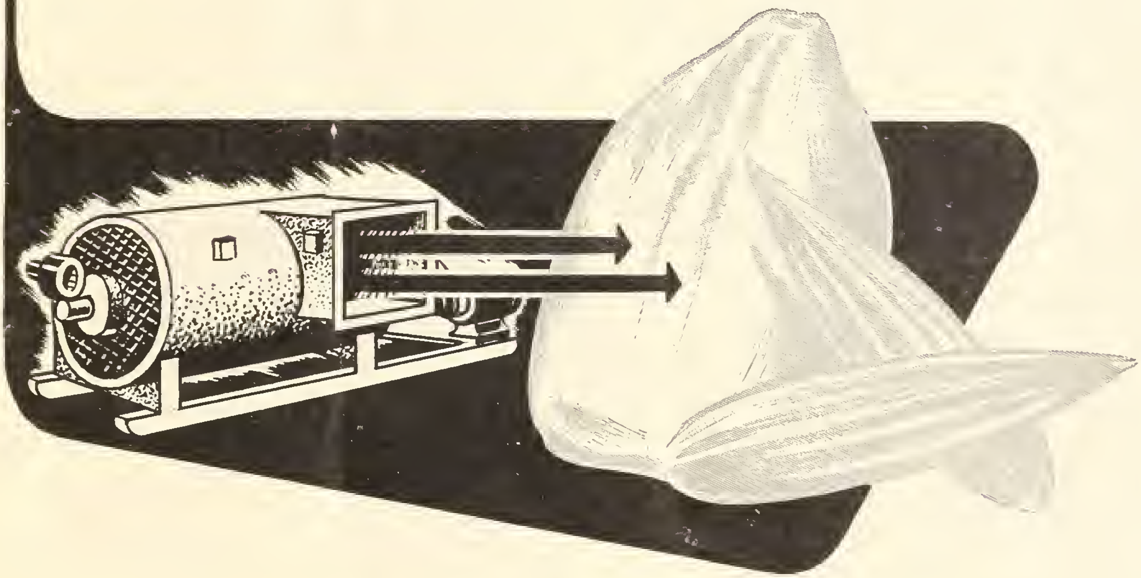
DRYING SHELLED CORN and SMALL GRAIN with HEATED AIR



Leaflet No. 331

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GRAIN DRYING ON THE FARM

Grain drying by mechanical ventilation removes many of the hazards of harvesting and storing crops. Such drying is valuable to you not only when you are faced with the emergency handling of high-moisture crops, but also as part of your regular crop-management program. Controlled drying fits in with modern production, harvesting, and handling methods. It overcomes the problems presented by the use of grain combines and mechanical corn harvesters—equipment that gets the crops out of the field quickly but often dangerously wet. The availability of electric and gasoline-engine power and use of such power in driers of modern design makes mechanical ventilation possible.

Crop drying is practical on the farm, if the following advantages outweigh the cost of drying:

A. Corn can be—
  1. Stored safely.
  2. Marketed without a moisture discount.
  3. Harvested early, thus taking advantage of good harvesting weather, reducing field losses from insects and bad weather, obtaining cleaner husking, lowering harvesting costs, and making possible fall plowing and seeding of wheat or cover crops.
  4. Shelled and stored in tight bins in half the space required by ear corn, thus reducing storage loss caused by insects, rodents, and unfavorable weather.
  5. Harvested with a picker-sheller.
  6. Saved in wet years.

B. Small grains can be—.
  1. Stored safely.
  2. Marketed without a moisture discount.
  3. Harvested as soon as mature, thus reducing the chance of storm damage while waiting for the crop to dry in the field.
  4. Harvested faster, by operating combines early in the morning and late at night.
  5. Combined directly, without windrowing.
  6. Saved even in wet harvesting weather, when, because of late seeding or poor growing weather, the crop must be harvested although it contains a high percentage of moisture.

The way to dry grain[1] is explained in this leaflet and the three others here listed, copies of which are available from your county agricultural agent, the Extension Service agricultural engineer at your State college, or from the Office of Information, the U. S. Department of Agriculture, Washington 25, D. C.

Leaflet 332, "Drying Shelled Corn and Small Grain With Unheated Air," outlines how unheated air can be used to reduce the moisture content of harvested grain to a point at which it can be stored safely on the farm or marketed without moisture discount.

Leaflet 333, "Drying Ear Corn With Heated Air," describes equipment needed and methods used in drying with heated air.

Leaflet 334, "Drying Ear Corn With Unheated Air," explains how unheated air can be forced through ear corn with good drying results and at low cost.

If drying crops with mechanical ventilation is new to you, the advantages and disadvantages listed below for both unheated- and heated-air drying may help you when considering your drying set-up.

Heated-Air Drying

Advantages:	*Disadvantages:*
1. Can dry wettest grain.	1. Higher initial equipment cost.
2. Can dry regardless of weather conditions.	2. Expense for fuel.
3. Short drying time.	3. Some fire hazard.
4. High drying capacity per fan horsepower.	4. Considerable supervision required.

Unheated-Air Drying

Advantages:	*Disadvantages:*
1. No expense for fuel.	1. Dependent on weather conditions.
2. No fire hazard.	2. Slow drying rate; usually several weeks.
3. Lower initial equipment cost.	3. With prolonged drying, grain may be damaged by mold growth.
4. Little supervision required.	

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[1] How to dry forage crops is described in Farmers' Bulletin 2028, "Drying Forage by Forced Ventilation."

Washington, D. C.

Issued September 1952

Drying Shelled Corn and Small Grain With Heated Air

SHELLED CORN and small grain can be dried for storage or market by mechanical ventilation with heated air in any kind of weather and from any moisture content. Fuel costs of drying will be about in proportion to the amount of water to be evaporated from the grain. (See table 2, p. 11.)

General Recommendations

1. Select drying equipment that will provide the necessary heated air flow at static pressures between 1 and 2½ inches, water gage. The heater should have a fuel-consumption rate that is adequate to heat the air to the desired drying temperature. One gallon of fuel oil burned per hour in a direct-heat drier should raise by 50° F. the atmospheric temperature of 2,350 cubic feet of air each minute (141,000 cubic feet each hour). The temperature rise would be somewhat less with an indirect drier.

2. It is recommended that corn to be marketed be dried with drying-air temperatures not above 140°. Higher temperatures may damage the corn for wet milling. Recommended drying temperatures are similar for small grains that are to be marketed. No serious reduction in feed value has been found when drying air at temperatures up to 200° are used, however. If the grain is to be used for seed 110° is about the highest drying-air temperature recommended.

3. Match the size of the batch of grain to be dried at one time to the size of drier. (See table 1, p. 10.)

4. Supply heated air at a rate that will dry the grain before it is damaged by mold growth or other causes, but at a temperature that will not damage the grain. (See table 1.)

5. When filling drying bin, spread any cracked grain and foreign material uniformly through the batch.

6. When drying very damp grain in warm weather, operate the drier continuously until the batch is dried. In cool weather the drier may be operated during the daytime only. Whenever the drier is stopped, cool the grain by letting the fan continue to run from 30 minutes to 1 hour after the heat is shut off.

7. Use good drying equipment with adequate safety controls and operate carefully. If you do this the fire hazard will not be great. Check with your fire insurance agent to be sure that you have adequate coverage when using heated-air drying equipment.

Equipment Requirements

Equipment that you will need for drying shelled corn and small grain with heated air includes a heater such as an oil burner, a power-driven fan, and a drying bin for the grain.

A number of fan and heater crop-drying units with power unit and controls mounted together are now available on the market. These units burn oil, natural or liquified petroleum (L. P.) gas, or coal. Most such driers are portable. Their effectiveness in drying grain depends on: (1) The rate at which heat is supplied (rate of fuel consumption per hour) and (2) the rate of air supply in cubic feet per minute (c. f. m.).

Driers are classed as "direct heat" and "indirect heat" driers (figs. 1 and 2, respectively). At least two automatic safety controls are needed with either kind of drier: (1) A device to shut off the

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drier if the flame fails, and (2) one to shut off the fuel supply if the temperature goes too high.

In the portable direct-heat crop drier shown in figure 1, burnt gases are combined with the heated air, and the mixture is blown through the grain. This type of drier uses fuel efficiently, but there is some fire hazard.

In the portable indirect-heat crop drier shown in figure 2 the burnt gases pass through the heat exchanger and are discharged through a smokestack. Air, heated as it comes into contact with the heat exchanger, is blown through the grain. Some heat is lost through the smokestack. The fire hazard is less than with a direct-heat drier.

The most important factors to consider in selecting a fan are design, size, and speed. Of secondary importance is whether the fan is a propeller or centrifugal type. Among the fans that are unsatisfactory for use in grain driers are house, attic, and barn ventilating fans; those used for blowing materials, such as silage and grain blowers; and types used in fanning mills. When a fan is incorporated in a drier, its rate of air delivery is reduced as compared to that shown in fan tables. The air-delivery rating of the drier should therefore be expressed in cubic feet per minute against the static pressure measured at the drier outlet. The static pressure when drying small grain will usually be from 1 to 2½ inches, water gage.

Drying Bins

Various types and features of drying bins are shown in figures 3 to 8.

The false floor of the circular metal bin shown in figure 3 is of perforated metal. Cover the floor with an even layer of grain before starting the drier. Recommended grain depths are from 1 to 5 feet. Place the perforated floor at least 16 inches above the permanent floor or ground if a conveyor is to be used beneath the floor. If a portable auger is to be used on top of the false floor make the height of this floor 10 to 12 inches. Support the false floor on wood framing and concrete blocks or on other suitable supports. Lay the blocks so that air can circulate through the openings. Provide one block for each 50 bushels of grain that can be placed in the bin. The perforation area should amount to at least 7 percent of the total area of the false floor. It is desirable that the floor be mounted in removable sections so that the space under the false floor may be cleaned easily. You can connect the drier at

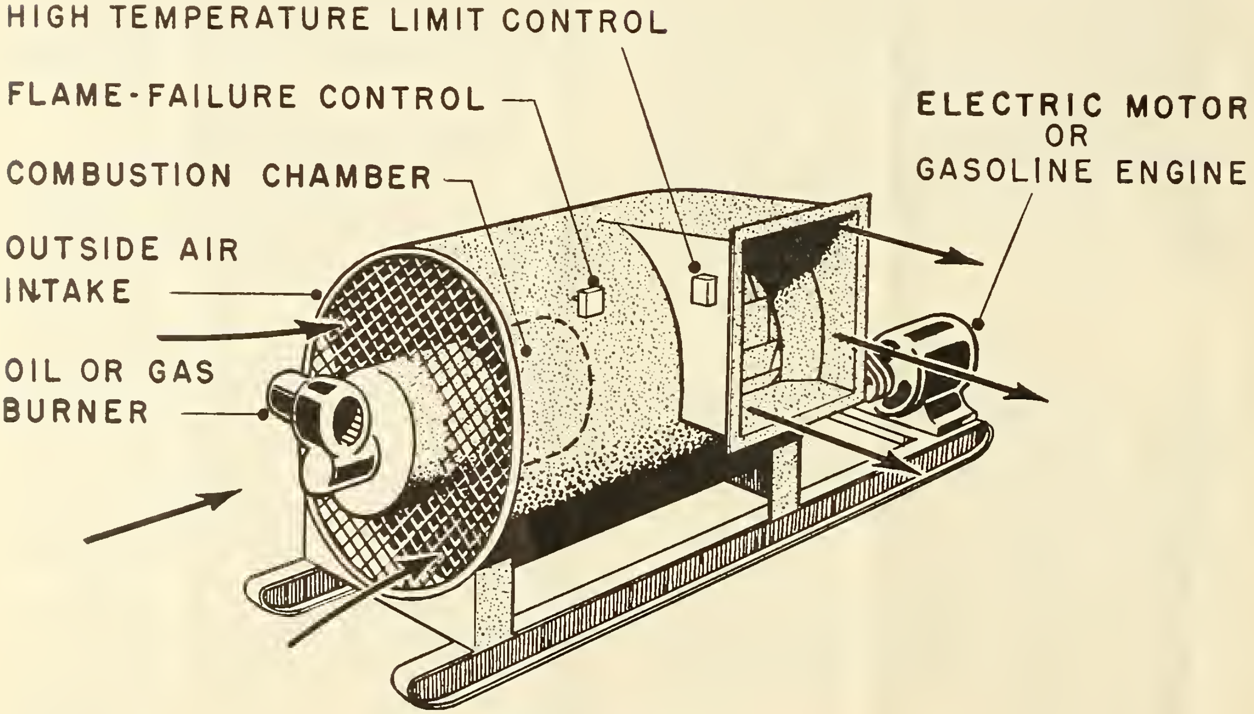

Figure 1.—*Portable direct-heat crop drier.*

the main bin door, but as you are likely to fill and empty the bins several times during a season, it is well to provide a separate inlet connection for the drier as shown in figure 3. Several companies make the perforated metal sheets that can be used for the false floors. These companies can also furnish plans for installing the floors. Perforated metal floors can also be used in other types of bins.

Hardware cloth can be used instead of perforated metal sheets as material for false floors in drying bins, as shown in figure 4. If openings are too large to hold grain, cover the cloth with screen wire. Lay the concrete blocks so that air will circulate through them. Rows of blocks laid 3 feet apart will support grain to a depth of up to 15 feet: rows 4½ feet apart will support grain to a depth of 9 feet.

A duct system that can be used in many types of bins is shown in figure 5. The duct system can be used in circular and rectangular bins, in overhead bins of combination crib-granaries, and in bins in a granary. For uniform air distribution the grain depth should be at least 3 feet. The main duct, shown in figure 5 outside the bin, could be located inside, along one side or at the center of the bin. Build the lateral ducts in about 4- to 6-foot sections, so that you can remove them easily while emptying the bin. Details on the construction of the duct system are shown in figure 6.

Construction details of a duct system that can be used in several types of bins, as just described, are shown in figure 6. The main duct is generally rectangular in shape, although it may be rounded or triangular. Provide 1 square foot of cross section area for each 1,500 c. f. m. of air flow from the fan. For example: If the fan delivers air at the rate of 6,000 c. f. m., provide a cross section area of at least 4 square feet for the main duct. The duct could be 2 feet square or a triangle with 3-foot sides. Provide small screened openings along the top of the duct if inside the bin so that air may pass upward to dry grain above the duct.

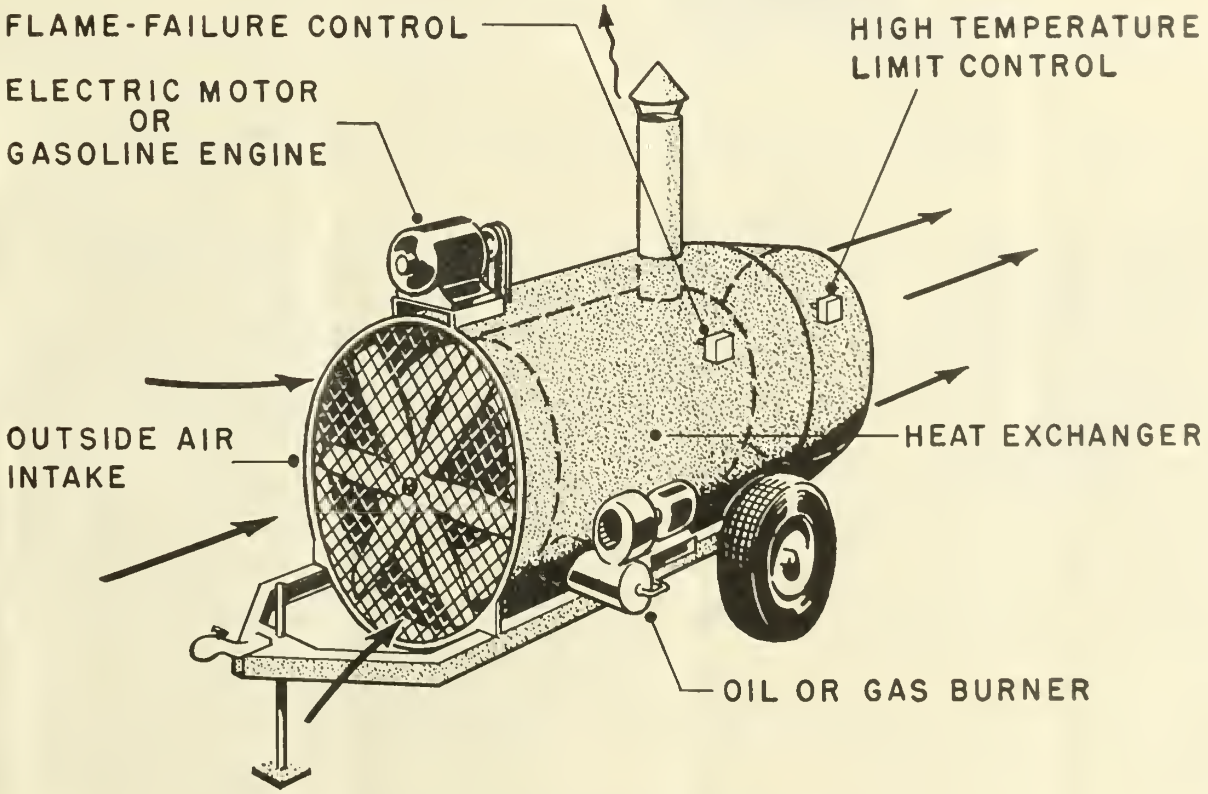

Figure 2.—*Portable indirect-heat crop drier.*

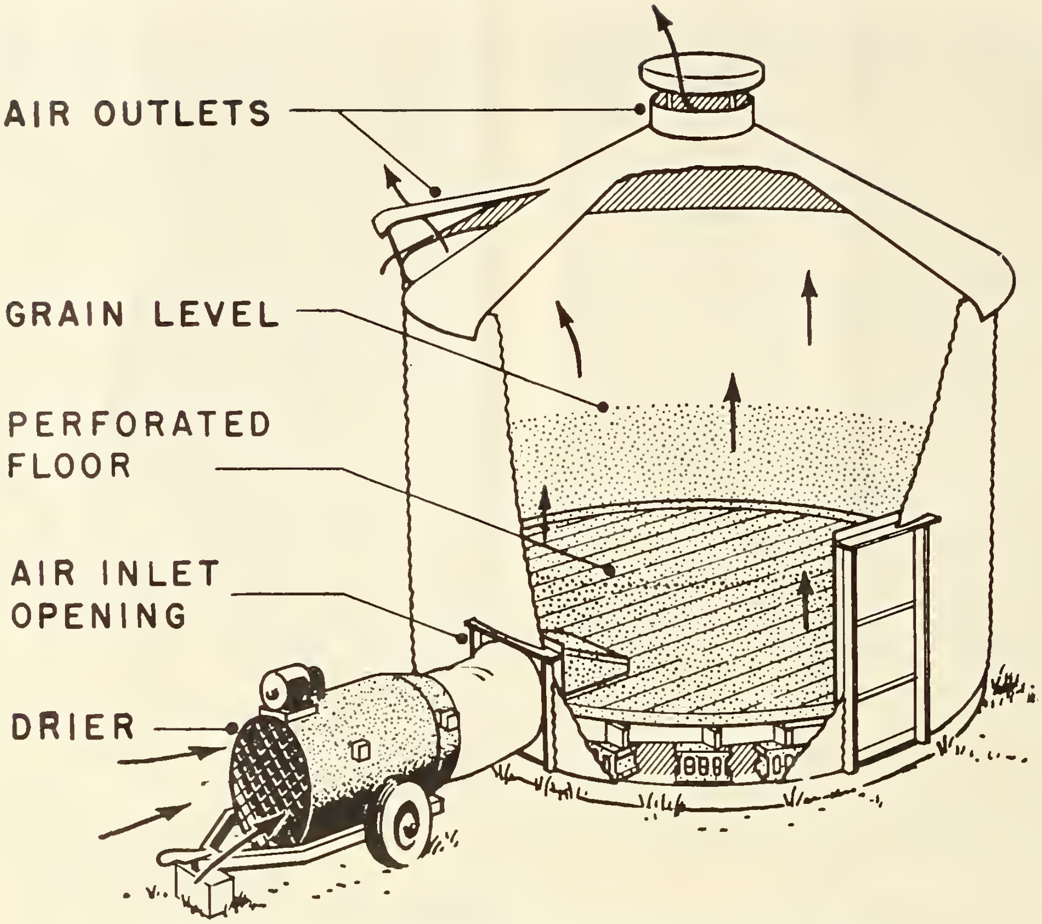

Figure 3.—*Circular metal bin with false floor of perforated metal.*

Space the lateral ducts, which can be rectangular, triangular, or rounded in shape, not more than 2 feet apart, center to center. If all the lateral ducts are of the same length, you can compute the cross section area required for each by dividing the cross section area of the main duct by the number of lateral ducts. For example: With 8 laterals of the same length and a main duct cross section area of 4 square feet, the cross section area of each lateral would be 4 divided by 8, or ½ square foot. If you were to build the laterals in rectangular form, one 1- by 12-inch board for the top and one 1- by 8-inch board for each side would be satisfactory for each lateral.

The width of each lateral should be at least twice the height of its bottom edge above the floor. This height should be about 4 inches for a lateral spacing, center to center, of 2 feet.

In any case, the total area for air passage under all the laterals (height from floor to bottom of duct times length of both sides) should equal at least one-fourth of the bin floor area.

If you use perforated metal sheets to make the laterals, and the sheets have uniformly spaced perforations equaling at least 10 percent of their total area, you may set the laterals directly on the bin floor.

The column drying bin shown in figure 7 has perforated walls. The walls can be made of either screen wire or perforated metal. You can make the bin either stationary or portable and you can use either a direct- or an indirect-heat drier. Heated air blown into a chamber between the columns is forced through the grain in the columns. The grain moves through the drying bin by gravity and is removed by a conveyor. Provide a cover if the bin is to be used outside. This unit can be used as either a continuous- or batch-type drier.

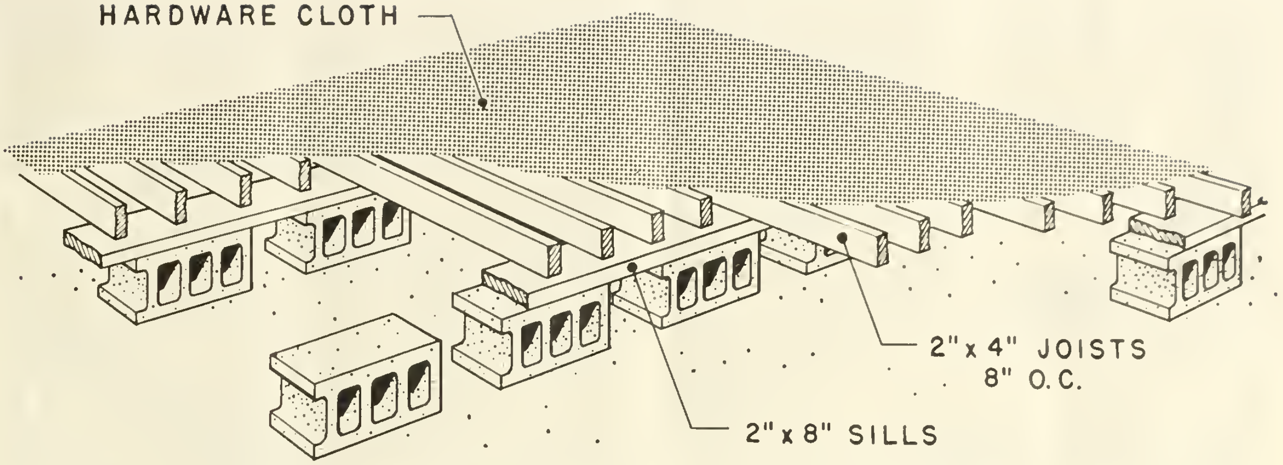

Figure 4.—*Method of using hardware cloth as a false floor in a bin.*

Several layers of ducts carry heated air through the grain in the drying bin illustrated in figure 8. This type of bin may be either stationary or portable. Either direct- or indirect-heat driers may be used. Grain in the bin surrounds supply and exhaust ducts, which are open on the bottom. Heated air, forced into the supply ducts, moves out of the bottom of the ducts, through the grain, and is expelled through the exhaust ducts. This unit can be used as either a continuous- or batch-type drier.

The drying bins illustrated in figures 3 and 5 have an advantage in that they provide some latitude in

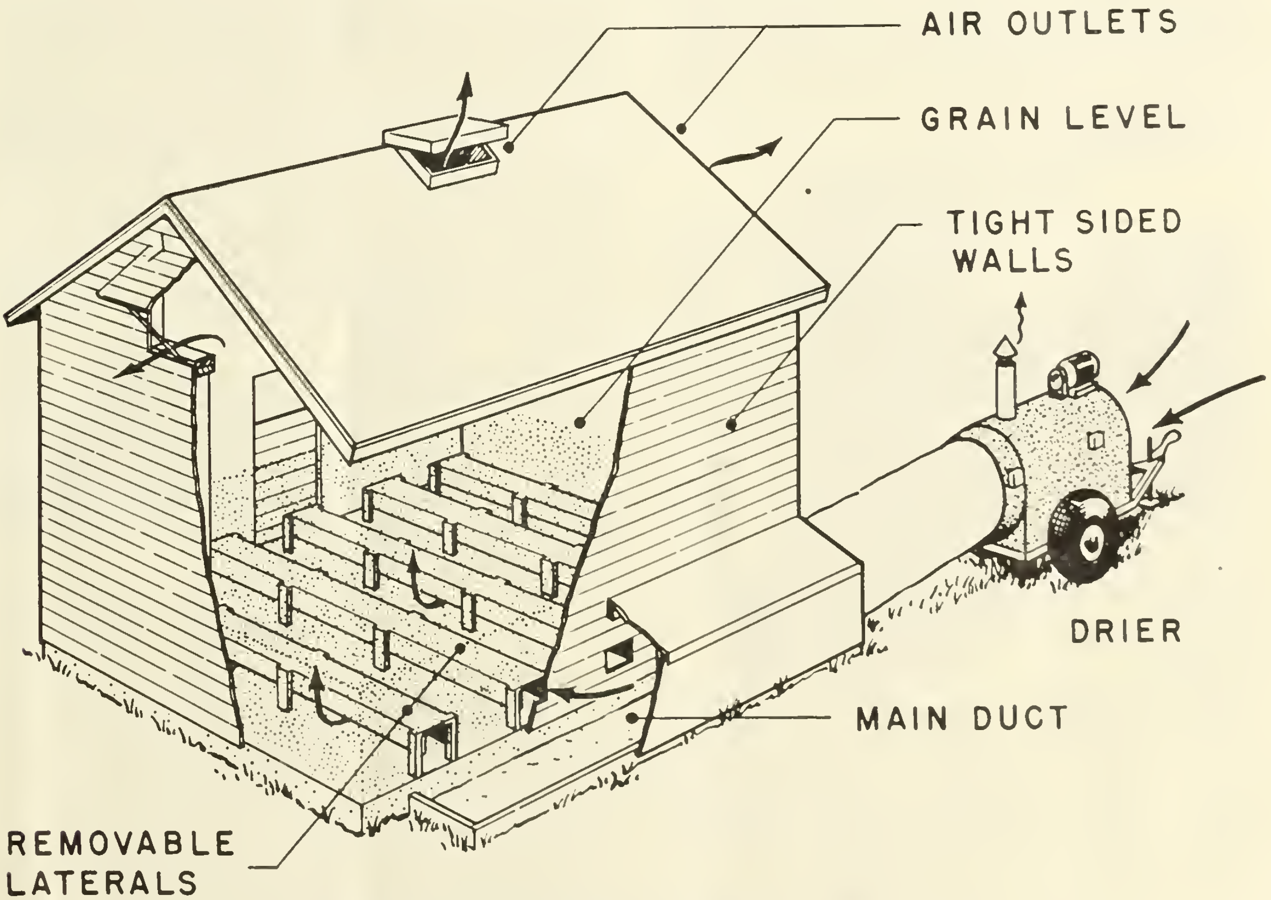

Figure 5.—*Rectangular bin with duct system.*

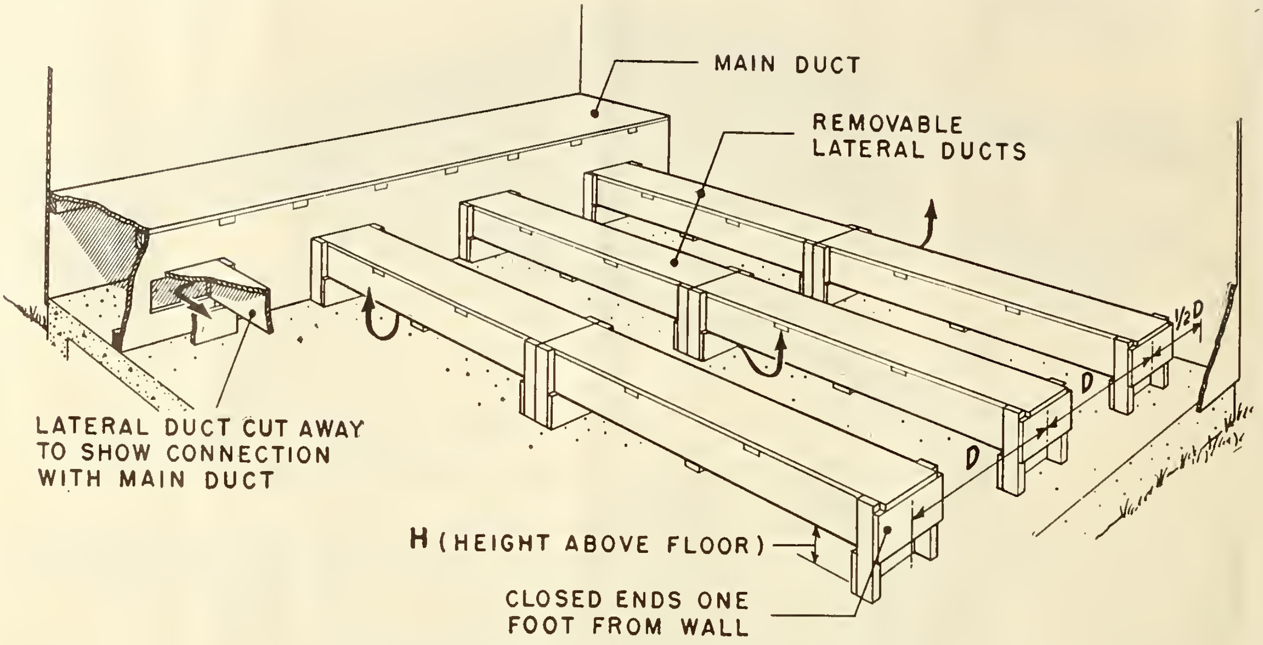
MAIN DUCT
REMOVABLE LATERAL DUCTS
1/2 D
D
D
LATERAL DUCT CUT AWAY TO SHOW CONNECTION WITH MAIN DUCT
H (HEIGHT ABOVE FLOOR)
CLOSED ENDS ONE FOOT FROM WALL

Figure 6.—*Details of duct system for drying bin.*

the size of batch that can be dried in them. In the bins shown in figures 7 and 8, the grain moves through by gravity and thus requires very little manual handling.

How Grain Dries

Heated air does not dry all of the grain uniformly. The grain that the incoming air strikes first dries faster than that on the exhaust side of the bin. When the average moisture content of grain dried with heated air is 13 percent, the moisture content of the driest grain will be less than 13 percent, and that of the wettest grain will be considerably higher. Hence, when drying is completed it is necessary to mix the batch so that during storage the percentage of moisture content will be more uniform throughout the grain. The grain usually becomes sufficiently mixed while being moved from the drying bin to the storage bin.

Settling

When grain dries, moisture loss causes the volume as well as the weight of grain to decrease. The higher the initial moisture content of the grain, the greater will be the amount of settling during drying. With drying bins as shown in figures 7 and 8, settling will waste heated air unless provision is made to prevent it. In the bin shown in figure 7, for example, it is necessary to load enough grain into the supply bin so that even after settling, the columns will be full; otherwise, air will escape over the settled grain. Also, some of the batch will not dry entirely because, as a result of settling, a small amount of damp grain moves into the columns after most of the batch is dried. The amount that is not dried is small and has little effect on the average moisture content of the batch when well mixed.

Cooling

You should cool the grain after drying it with heated air. You can do this by operating the fan after the heater has been turned off. Blowing with unheated air for ½ to 1 hour will usually cool the grain to within a few degrees of the atmospheric temperature. Some additional drying will occur while the grain is being cooled.

Drying Capacity

For any moisture range the number of bushels that can be dried per hour depends largely on the rate and efficiency of fuel consumption. The more fuel burned, the greater will be the quantity of grain that can be dried. If the size of the drying bin is too small, however, or if the temperature cannot be raised high enough, the heat cannot be used to good advantage—and burning increasing amounts of fuel will not result in much increase in drying capacity.

The size of drying bin to use depends on the amount of heat and air supplied by the drier, the moisture in the grain, weather conditions, and the temperature of the drying air. For this reason no one size or design of drying bin is best for all conditions.

The relation between such factors as grain depth, fuel-consumption rate, volume and temperature of drying air, and drying time for a bin with 250 square feet of drying area, for a few specific conditions, is shown in table 1. In bins similar to those illustrated in figures 3 and 5, the drying area would be the floor area. In bins similar to those shown in figure 7, the drying area would be the combined area of the inside walls of the two drying columns. The grain depth in these column driers would be the thickness of the column. In the bin shown in figure 8, the drying area would be the cross section area of the bin multiplied by the number of layers of grain between the rows of ducts. Grain depth in this type of bin is the distance from the bottom of one row of ducts to the bottom of the one above, and not the total depth of grain in the bin.

Results to be expected under other conditions of drying operations than those shown in table 1 are:

1. *Use of less than 5-hp. motor.*—If it is necessary to use a smaller than 5-hp. motor with a given batch size and depth of grain, the air flow will be reduced. If the fuel-consumption rate remains the same, the temperature of the drying air will be higher.

2. *Other initial moisture contents.*—With the same drying equipment used in table 1 but with lower initial moisture content of the grain, the drying will be finished more quickly. The drying capacity will therefore be greater. The time required to dry the grain will be roughly proportional to the amount of water removed. An estimate of how much water must be evaporated from a bushel of grain at various percentages of initial moisture content can be made by reference to table 2.

3. *Other fuel-consumption rates.*—Reduction of the fuel-consumption rate results in lower temperature of heated air and less drying capacity.

4. *Other atmospheric conditions.*—With a given fuel rate, drying is faster during the warmer days. If the same drying temperature is maintained in cold weather as in warm weather, drying will be just as fast but it will be more expensive because of greater fuel consumption. With heated-air drying, the rel-

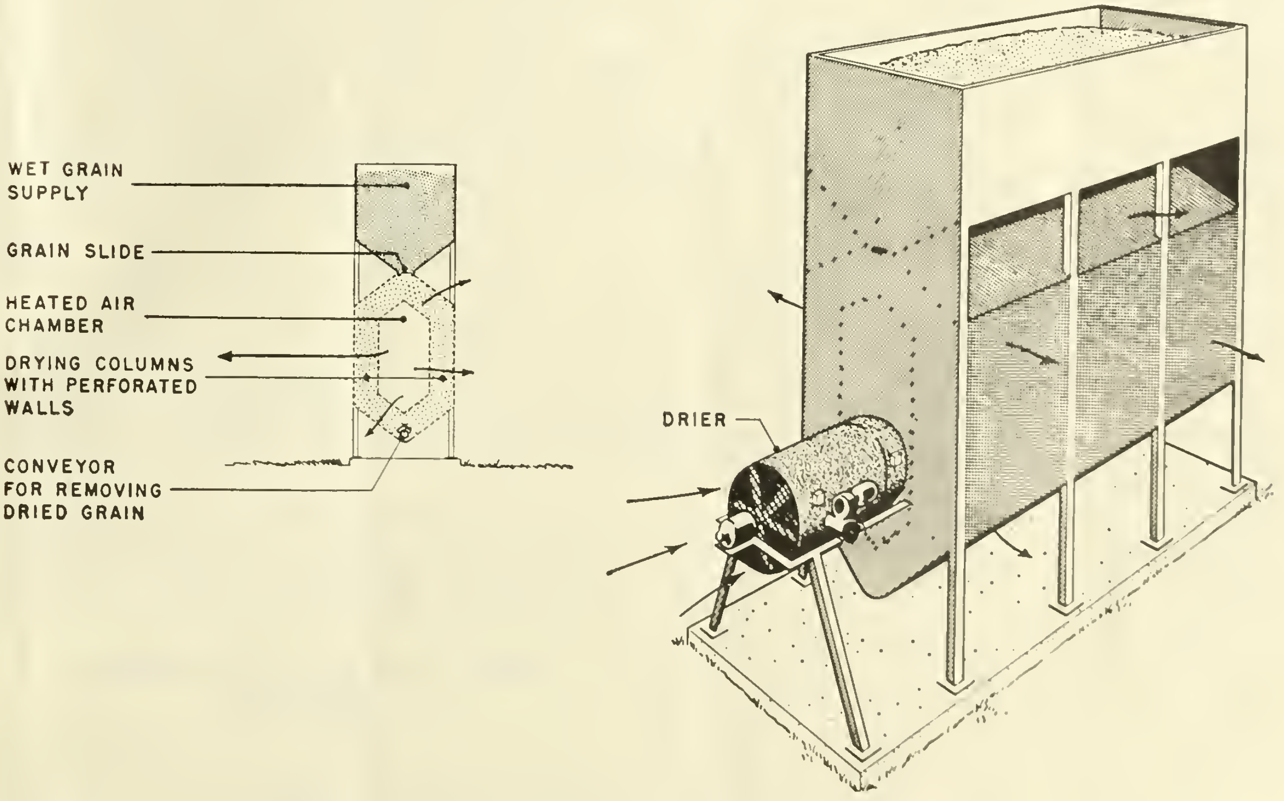
WET GRAIN SUPPLY
GRAIN SLIDE
HEATED AIR CHAMBER
DRYING COLUMNS WITH PERFORATED WALLS
CONVEYOR FOR REMOVING DRIED GRAIN
DRIER

Figure 7.—*Column grain-drying bin with perforated walls.*

TABLE 1.—*Relationship of depth (thickness) of grain, drying time, and temperature for a bin with 250 square feet of drying area, when using 5 hp. on the fan and burning 5 or 10 gallons of fuel oil per hour in a direct-heat drier*

Depth of grain (feet)	Air volume	Static pressure	Bin capacity	Burner with fuel consumption of—			
				10 gallons per hour		5 gallons per hour	
				Drying temperature	Drying time	Drying temperature	Drying time
	C. f. m.	*Inches, water gage*	*Bushels*	*° F.*	*Hours*	*° F.*	*Hours*
SHELLED CORN DRIED FROM 25 TO 13 PERCENT MOISTURE (ATMOSPHERIC TEMPERATURE 50° F.)							
1	14,500	0.96	200	131	[1] 5.0	......	......
2	11,200	1.26	400	155	[1] 5.0	102.5	13.7
4	8,800	1.64	800	184	8.1	117	19
SHELLED CORN DRIED FROM 20 TO 13 PERCENT MOISTURE (ATMOSPHERIC TEMPERATURE 50° F.)							
1	14,500	0.96	200	131	[1] 3.2	......	......
2	11,200	1.26	400	155	[1] 3.0	102.5	08.3
4	8,800	1.64	800	184	4.8	117	10.8
WHEAT DRIED FROM 20 TO 13 PERCENT MOISTURE (ATMOSPHERIC TEMPERATURE 70° F.)							
½	13,700	1.12	100	156	1.5	113	4.1
1	10,000	1.38	200	187	1.4	129	3.9
2	7,500	1.80	400	......	......	148	5.1
4	5,750	2.48	800	......	......	172	9.2
OATS DRIED FROM 20 TO 13 PERCENT MOISTURE (ATMOSPHERIC TEMPERATURE 70° F.)							
½	15,000	0.91	100	148	1.4	109	4.1
1	11,750	1.2	200	170	1.2	120	3.5
2	8,750	1.56	400	......	......	137	3.4
4	6,750	2.1	800	......	......	157	5.4

[1] As shown in this table the drying time for 200 bushels of shelled corn, 1 foot deep, is about the same as for 400 bushels, 2 feet deep. That is because there is not a good balance between batch size, fuel-consumption rate, and temperature of drying air at the 1-foot depth. The air supply for the 1-foot layer could be cut down by reducing the fan speed, thus giving a greater temperature rise and better efficiency.

ative humidity of the atmosphere is of small importance. The efficiency of drying is little affected even during rainy periods.

5. *Other temperatures of drying air.*—The temperature of the drying air has a great influence on the rate at which moisture can be removed from grain. As batch size is decreased, the drying capacity can be kept at the same hourly rate by raising the temperature of the drying air. There are limitations, however, on the drying-air temperatures that can be safely used. (See General Recommendation No. 2 for recommended drying temperatures.)

Weight Loss Caused by Moisture Reduction

Table 2 shows the amount of water in grains at various percentages of moisture content. By using this table you can estimate the weight loss (number of pounds of water evaporated) caused by drying. Subtract the weight of water per bushel after drying from the weight of water per bushel at the start of drying.

Another method of calculating weight loss is by the following formula:

$$\text{Initial weight} \times \frac{100 \text{ minus initial percent moisture}}{100 \text{ minus final percent moisture}} = \text{final weight.}$$

Then, initial weight minus final weight = weight of water lost.

For example, if 20,000 pounds of grain with a moisture content of 25 percent is dried down to 13 percent, the weight after drying will be $20{,}000 \times \frac{100 \text{ minus } 25}{100 \text{ minus } 13} = 20{,}000 \times \frac{75}{87} = 20{,}000 \times .86 =$ approximately 17,200 pounds. This represents a weight loss of 2,800 pounds (weight of water lost by evaporation).

Estimating Fuel Requirement

Having estimated the weight loss of water, the gallons of fuel oil required to dry the batch can then be estimated as follows: If using a direct-heat drier, divide the weight loss by 85 for summer conditions, 70 for fall, and 50 for winter. With an indirect drier use 60 for summer conditions, 50 for fall, and 35 for winter conditions. Suppose, for instance, that the 20,000 pounds of grain in the example just given is to be dried in October with an indirect-heat drier: The estimate of the amount of fuel oil required would be:

$$\frac{2{,}800}{50} = 56 \text{ gallons of fuel oil.}$$

The estimated fuel oil consumption given illustrates what you can expect from a properly planned farm grain-drying system when there is a good match between the size of drier and the size of each batch of grain.

How To Tell When a Batch Is Dry

A practical method of determining when a batch will be dry consists of estimating the amount of fuel that will be required to dry the batch to the desired moisture content, as explained. When this amount of fuel has been burned, start checking the grain moisture content by taking probe samples. When the grain is nearly as dry as desired, shut off the burner and cool the grain.

TABLE 2.—*Pounds of water per bushel*[1] *of grain at different moisture-content percentages*[2]

Grain moisture content (percent)	Amount of water per bushel of—		
	Shelled corn and grain sorghum (Pounds of dry matter per bushel = 47.32)	Wheat and soybeans (Pounds of dry matter per bushel = 51.6)	Oats (Pounds of dry matter per bushel = 27.4)
	Pounds	*Pounds*	*Pounds*
35	25.4	27.8	14.6
30	20.2	22.1	11.7
28	18.4	20.1	10.6
26	16.6	18.2	9.6
24	14.9	16.4	8.6
22	13.3	14.6	7.7
20	11.8	12.9	6.8
18	10.4	11.4	6.0
16	9.0	9.8	5.2
14	7.7	8.4	4.4
12	6.5	7.0	3.7
10	5.3	5.8	3.0
8	4.1	4.5	2.3

[1] A bushel is defined here as the amount of grain required to yield 56 pounds of shelled corn or grain sorghum at 15.5 percent moisture, 60 pounds of wheat or soybeans at 14 percent, and 32 pounds of oats at 14.5 percent.

[2] To determine the number of pounds of grain required to make a bushel at a given moisture percentage, add the pounds of water to the pounds of dry matter (shown at head of column). For example: To obtain the weight of corn, at 28-percent moisture content, to make a bushel, add the pounds of water (18.4) to the pounds of dry matter per bushel (47.32). This totals 65.7 pounds. It requires 65.7 pounds of corn of 28-percent moisture content to make a bushel (56 pounds) of 15.5 percent corn.

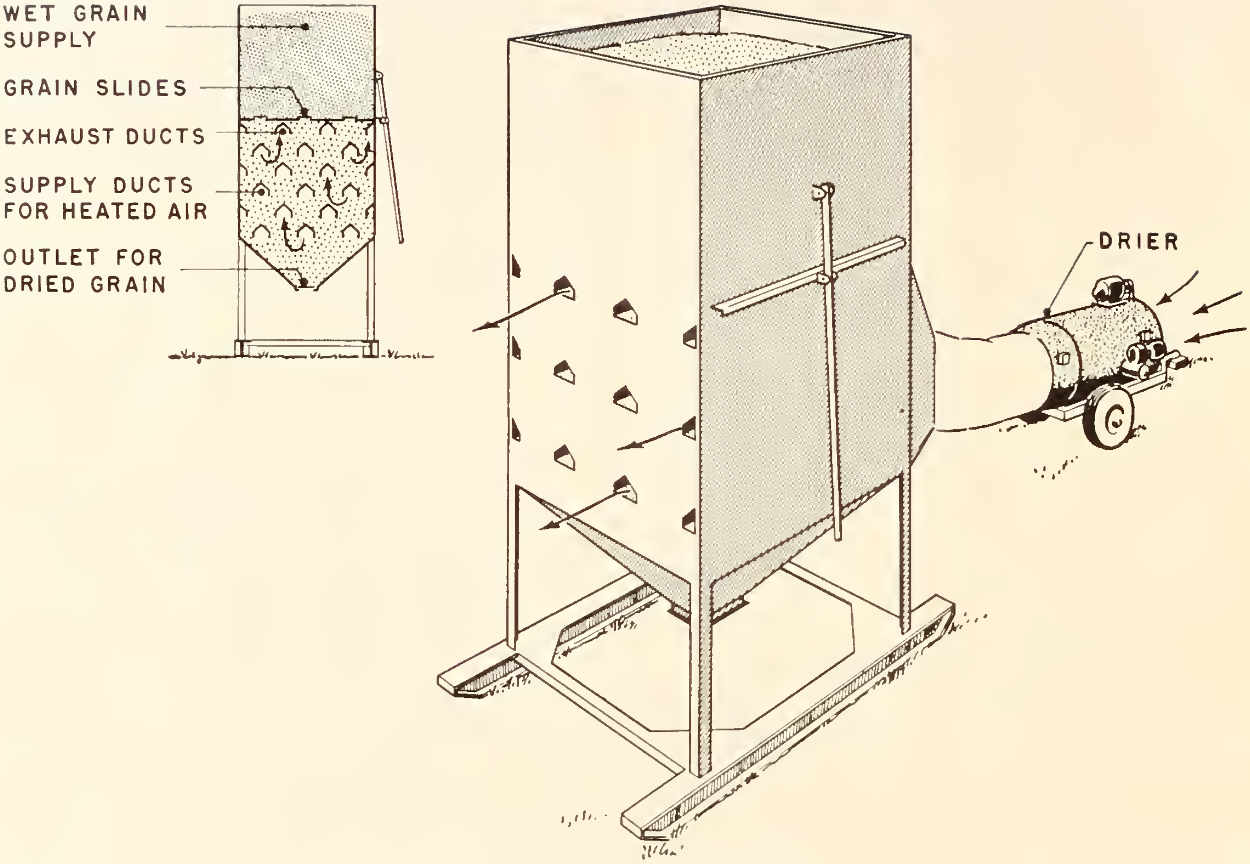

Figure 8.—*Drying bin with ducts through the grain.*

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